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USING

ROOT GROWTH CAPACITY

FOR

EVALUATING SEEDLINGS

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BY

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SIUSLAW NATIONAL FOREST

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Thesis/
Reports
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ABSTRACT

Tree seedlings have been planted with varying degrees of success with survival for many years. A problem with planting tree seedlings from several nurseries has been the absence of an adequate testing method for evaluating seedling quality. There are several types of tests available to evaluate seedling quality but only one, Root Growth Capacity,(RGC) gives potential survival in time to modify planting plans. Root Growth Capacity testing is accomplished in a controlled environment using an actual sample of the seedling lot. Uniform conditions are used to test all seedlots similarly. Results of the test are available in 4 weeks and can be used to modify planting requirements to obtain the desired stocking level in each plantation. Test results have been field checked for several years to make the Root Growth Capacity (RGC) test a reliable and relatively easy test to predict seedling quality prior to planting.

INTRODUCTION

Tree seedlings have been planted for many years in the forests. There have also been many plantation failures due to many causes. One of the reasons given for failure of planting stock has been receiving poor quality stock from the nursery. Testing seedlings by using the root growth capacity test can establish whether the nursery stock is adequate. Root growth capacity measurements can predict the ability of a tree to grow. Root growth capacity is a measure of a tree's ability to produce new roots when planted in a controlled environment. A greenhouse, with temperature, moisture and light controls, provides an ideal growing environment for testing trees under controlled conditions. The ability of a tree to grow roots has been tested for correlation with field survival.

The lifting window study (Humboldt Nursery Administrative Study (RF432A02) was used to establish lifting windows for seedlings at Humboldt Nursery.[1] This same principle is used to measure the Root Growth Capacity (RGC) of any seed lot. The results of the test then give a predicted survival rate for the seedlings, which is based upon the seedlings physical condition at the start of the testing period. Handling and storage of the seedlings after the test period will not be tested, therefore if any of the seedlots fail after being tested as satisfactory, the cause of the problem will probably be in the storage and handling of the seedlings after removal from the nursery. This will help eliminate at least one major cause of failure by being able to

pinpoint the condition of seedlings coming from the nursery. A study undertaken in Arkansas by Brissette and Roberts[2] compared the seedling size and lifting date affects on the Root Growth Potential of loblolly pine (Pinus taeda). Burdett, in an article in the Canadian Journal of Forest Resources described a method for measuring root growth capacity in assessing lodgepole pine.(Pinus contorta)[3] In 1980, Ritchie and Dunlap described root growth potential in tree seedlings in New Zealand.[4] Field results have been correlated with tested results so that the readings obtained by the RGC tests are very indicative of what to expect from the tests.

Root Growth Capacity is described by J. L. Jenkinson as the seedlings capacity to grow as measured by the amount of new root growth in a given period of time under controlled conditions.[8] As long as the conditions are kept constant for all seedlots, then a comparison can be made between seedlots. Trees are tested in a green house environment where conditions can be controlled for the entire growing cycle of 28 days. Trees are grown under optimum growing conditions and then the new roots starts are physically counted and compared to the standard. Evaluation is done immediately after removing the trees from the growing medium on the last day. The number and length of new roots is significant to determine the quality of the tree. RGC at the time of planting explained 99% of the variation in 1-year survival.[8] The estimated critical values of RGC were 10 actively elongating roots at 28 days.

MATERIALS AND METHODS

As a result of the lifting window studies, the relationship between field survival and root growth capacity (RGC) of stored seedlings at planting time, together with the seasonal pattern of RGC in the nursery, was established. The correlation of RGC to field survival and growth is now available for *silviculturists to use on an operational basis as a result of the special studies unit at Humboldt nursery. A similar testing facility was constructed in 1983 at the Beaver Creek nursery on the Siuslaw National Forest for evaluation of seedlots prior to planting on the Siuslaw National Forest.

The test facilities consists of a green-house and a water bath bench for controlling growing conditions.(Appendix C) The water bath bench unit consists of 3 separate but identical units with each one having 4 separate compartments. Each compartment has a separate tank that has individual temperature controls to control the water temperature. Individual control of each tank allows for the control of the root temperature on each seed lot. Individual seed lots are planted in stainless steel trays of sufficient size and depth to hold approximately 10 seedlings. Each tray is deep enough to hold the root system of the tested trees. Up to eight trays can be placed in each compartment in testing bench. The seedlings are planted in a soil mixture of peat, vermicullite and loam that is optimum for good root growth initiation. Each lot is planted in an identical mix so the roots

in each lot have an identical medium for growing. Air temperature, available light, and humidity are all controlled by the green-house environment. Supplemental light is provided by using a time controlled light source. Physical factors affecting tree growth are thereby regulated to afford optimum conditions for the seedlings growth and development.

Light is supplied by both natural and artificial means to provide a 16 hour photoperiod day. Air temperature is kept near 75 degrees in the daytime and 62 degrees at night. Soil temperatures are kept near 68 degrees at all times. Seedlings are maintained in the water baths for four consecutive weeks. Seedlings are maintained each week to add water to the individual container to bring it back up to its original water content. At the end of the fourth week, the seedlings are evaluated for actual root initiation. Each tree is evaluated by counting the number of new roots that have been initiated in the past four weeks and how much each new root has grown. The roots that have grown more than 1.5 centimeters are tallied and the totals for each tree are compared to the standards to determine the seedling quality. An important feature of the RGC test is the correlation of field testing of the ability of the tree to grow in field trials.

Once the initial set-up is completed, testing of seed sources is limited only by the physical capability of the facility. (Appendix B) The present bench setup can treat 24 lots at any given time. There is no correlation with this technique of evaluating seedlings and with existing tests such as the OSU

stress test. The results of the RGC tests are available within 30 days of initiation and are field correlated for reliability. Other tests, such as the stored reserves capacity, also have not been correlated with the RGC tests. Fish tank testing at Beaver Creek using only 10 trees per seed lot has not been statistically proven to be an adequate test for RGC.(9)

An early indicator of seedling condition is available in monitoring the amount of water an individual seed source is using during the 4 weeks of growth in the testing facility. Although it has not been correlated with final results, it is an early indicator of initiation of tree growth. The more water that is used, the higher the rate of metabolism for the individual trees in the tray. Those lots that use the most water have been those that have also shown the most root growth at the end of the four weeks. This observation has not been tested however, to be an adequate indicator of actual RGC.

There are other seedling tests available that can measure several parameters of a new seedling. These include the bud dormancy test, nutrition evaluation, stored reserves, water relations test, carbohydrates test, morphology test, stress resistance, and frost hardiness tests. All of these tests were designed to measure some aspect of seedling performance. The RGC test can be beneficial because of its simplicity in performance and most importantly, its correlation to field performance of seedlings. Some of the other tests were developed to establish lifting windows, but have not been field tested.

Frost hardiness can be measured but the results have not been fully correlated with field performance. By the time the results of the frost hardiness test are available for use by the field, the tree lot being tested has already been planted. This means that the results are known after the fact and long after the need for them. Morphological measurements do not give any indication of whether the poor growth is from poor handling or storage conditions, or from poor quality seedlings from the nursery. The dormancy release index may be of little value when lifting windows are already established for a given nursery. (1)

Testing seedlings on an operational basis requires that facilities be available to test the seed sources being outplanted. Seed sources are selected from those trees currently being scheduled for planting. Once a seed source or seedling lot is selected, then a random sample of 100 trees is selected for testing. Trees are selected from several bags or boxes in order to get a random sample of trees from the seed lot. Once the initial 100 trees are selected, they are then sent to the test facility at Beaver Creek. Here, further selection is made to select the 30 trees of the 100 that will represent the average of the seed lot. (Appendix B) These 30 trees are planted in the trays (10 trees per tray) and then each tray is watered to saturation and weighed. Watering is done in small amounts until free water passes through the unplugged hole in the bottom of the tray. The tray is then left standing for at least 12 hours before the bottom is plugged to allow excess water to drain from the tray. The weight of the unplugged tray is recorded and used

as the basis for measuring water use for the week and the entire growing period. The tray is then placed in the water bath. The remaining 70 trees are kept in storage as a reserve for later testing if something should happen to the initial tested lot, or if a retest is necessary to confirm the results of the first test. If no retest is necessary, the 70 remaining trees can be planted as regular production trees in the field.

The trays of 10 trees each are placed in the water bath so that the root temperature (and the planting medium temperature) can be maintained at the 68 degrees temperature. Up to 8 trays can be placed in each compartment. Separate compartments are used to insure that trees can be tested even if there is a malfunction in one of the compartments. Separation of seed lots can also be used as an indicator for comparing results between seed sources. If a source doesn't do well in one compartment and other seedlings of other lots do well in that compartment, then it is probably the seed-lot rather than the test facility that is causing the poor performance. If all of the trees in the compartment do poorly, then the test table compartment is probably not properly adjusted. Trees are watered sufficiently at the beginning of the test, thereafter additional water will be needed each week. At the end of the week the trays are removed from the water baths, the plugs in the bottom of the trays removed, and the trays are weighed. The weights are recorded and water added to bring the tray weight back to the original weight at the time of initial placement in the water bath. This procedure is done each week for three weeks. At the end of the

fourth week, the trees are removed and the roots measured and counted.

The green house environment and the water baths are controlled to maintain optimum growing conditions for the trees during the four weeks. A refrigeration system that can keep the water in the water baths cooled is essential to maintain the temperature difference between the air temperature (75° during the day and 62° at night) and the soil temperature (68°). Sixteen hours of daylight is maintained by using an artificial light supplement in the green house. This set of growth conditions is very close to ideal for root growth initiation and development.[9]

The only maintenance needed during the four week testing period is to weigh and water the seed lots once each week. Other growth conditions are maintained by the green house facility and the water bath table. Personnel requirements for running the tests are very minimal. Time is required to select the 30 trees, plant the trees in the trays, and water them initially. After initial preparation, the only weekly maintenance required is to weigh and water each tray. The final step in the testing process is to remove the trees from the trays and count the new root growth.

The basis for evaluation of the Root Growth Capacity is to measure the number of new roots that were initiated during the four week testing period. This measure of the plants capacity for growth is correlated with field survival and growth. The initial testing of root growth capacity has determined that of the 30 trees in the test, at least 90% should have at least 10 new roots

that are 1.5 cm or longer on each seedling.[8] If this standard is met, then the seedling lot will survive in the field at a rate of 90%. If the amount of roots exceed the total of 15 centimeters of growth, then the trees will perform at a higher percentage rate in the field. For example, if 95% of the trees have 10 roots or more with the 1.5 cm growth, then the field survival rate should be 95%. There is a percentage increase in growth and survival with the higher rate of root production and growth. Tested trees that exceed 50 or more roots that equal or exceed the 1.5 cm of growth will grow and survive on almost any site, even under most severe conditions.[9] The potential for this type of tree on any site is practically unlimited. The other end of the spectrum is the tree that doesn't perform in the water bath. A tree that produces less than 10 roots that are less than 1.5 cm will also perform poorly in the field in the same ratio as the sample trees do in the test facility. A satisfactory tree should produce a minimum of 15 cm of new root growth on a total of at least 10 new roots.[5] Samples of less than 30 trees in a given seed-lot test will not give statistically reliable results. With lots of less than 30 trees, the results may or may not be indicative of field performance. Samples of 10 trees per lot have been grown in a fish tank with water for the growing medium rather than the soil mixture. Results of the tests of individual seed lots are similar to the results of testing 30 trees per lot in the soil medium but have not been tested for statistical reliability. Jenkinson has found that tests of less than 30 for RGC testing has been unreliable in the past and will likely be unacceptable for lots of less than 30 trees.[9]

RESULTS

The results of the RGC tests are read at the end of the four week testing period. Each tray is taken from the water bath and the root systems are carefully washed to remove the planting medium. Each tree is then examined for new root development. Individual new roots are counted and measured to determine the number of roots that exceed the 1.5 cm in length. The initial studies have indicated that the correlation with field survival data is significant only with those roots over 1.5 cm.(6) The time required to analyze each sample is relatively small except for the final stage of the examination. This step requires care so that the new roots are not broken off or damaged and an accurate count can be made. Results are tabulated on record sheets and a summary of the lot is completed.(7)

The individual cost per lot for conducting the entire test is $86.00. This is small a small amount compared to the results that can be achieved by completing the test and the savings in the number or trees to be planted. Evaluation of a poor seed lot can more than offset the cost of the tests, resulting in a better, healthier plantation. When the tests are scheduled on a planned basis, one person can do the entire process. The only exception could be in the last phase of counting the roots. When only six lots are established each week, then one person can easily handle all but the final phase of the tests. Six lots is the most that should be started in any given week because of the

layout of the facilities. Twenty four lots can be tested or in the test facility at any given time. Reading the results and planting the new lots takes the most time, therefore this should be spread out over the four week period. This way all 24 lots do not become due at one time. With six new lots started each week, there are only 6 that need to be started and six that need to have the final reading each week. An exception is when all of the seed lots are doing extremely well and time doesn't need to be expended to examine each tree after 50 new roots 1.5 cm. in length are found.

Examples of the results of seedlots tested in 1984 and 1985 are shown in Appendix A. In Example 1, a 2-0 seedlot from Humboldt nursery was installed in the RGC facility on February 2 and removed Mar. 1. 17 of the 30 sampled trees had 50 or more new roots of at least 1.5 cm. in length. This indicates that those trees are in very good condition, have been stored in suitable conditions, and lifted within the established lifting windows. This lot should do very well in the field under most any condition. It should survive at 95% or better and grow at least 15 cm. the first year. Example 2, shows a different seedlot with only 83 percent survival. This seedlot wouldn't be expected to do as well in the field. Its survival should be approximately 80% and growth will be less than 15 cm.

The results of the RGC tests are easy and straight forward to interpret. The results of field testing over the past several years have demonstrated the relationships of seedling survival to

the results of the RGC tests. Any seed lot that meets the minimum "growth potential" will survive and grow at that same rate in the field. The minimum standard established for Humboldt stock in the window of lifting study is 10 new roots of at least 1.5 cm. in length for each tree in the lot. This is the base level for 90% survival. If the number of new roots exceed this base, then the survival percentage goes up in proportion to the percent of trees exceeding the standard.

The following table is an estimate of what it would cost to test one seed lot. Five other seed lots can be tested concurrently.

RGC COST ESTIMATE FOR ONE SEED LOT

FACILITIES AND EQUIPMENT		
Refrigeration-Heating for 4-week period	$ 30.00	
Maintenance of RGC supplies and equipment	$ 4.00	
Planting Mix (per lot)	$ 3.00	
SUBTOTAL FACILITIES		$ 37.00
LABOR* TIME PER LOT-3 PHASES OF OPERATION		
PHASE 1--INSTALLATION 2 HOURS TO SELECT, CLEAN TRAYS, PLANT, WATER, WEIGH, AND RECORD INFORMATION	$ 13.00	
PHASE 2--MAINTENANCE FOR 4 WEEKS, WEIGH, WATER, AND RECORD WEIGHTS EACH WEEK AT 1/2 HOUR PER LOT FOR 3 TIMES	$ 9.75	
PHASE 3--READ RESULTS REMOVE FROM TRAYS, WASH ROOTS, COUNT INDIVIDUAL ROOTS, RECORD RESULTS, 1 1/2 HOURS PER LOT	$ 9.75	
SUBTOTAL -- LABOR		$ 32.50
OVERHEAD AT 23%		$ 16.00
TOTAL FOR ONE SEEDLOT OF 100 TREES WITH 30 SAMPLED.		$ 85.50
ROUNDED TO		$ 86.00

* Based on $6.50 per hour for labor cost.

DISCUSSION

Until the RGC test was developed, there was no easy way to evaluate planting stock quality prior to planting. With the inception of the RGC test seedlings can be evaluated beginning with the time they are lifted, until the need to evaluate is no longer present. Some earlier tests, such as the stress test at OSU, took a long time to evaluate and results were generally not available until long after the seed lot had been planted. There also is no correlation of the stress test results with field results. The RGC test can be completed before a seed lot is planted in the field and changes in planting plans can be made depending on the outcome of the RGC tests. The manager can make decisions based on test results rather than assumptions.

The RGC tests were established as a result of the Window of Lifting Studies at Humboldt nursery and were used as a way of evaluating the time periods that were available for lifting of stock at Humboldt nursery. Field trials were used to correlate the results of the studies. The field trials were established within the actual seed zone and elevational range of the tested seedlings. Almost all of the early work was done with Douglas fir (Pseudotsuga menziesii); however, there were some early tests with Jeffrey pine (Pinus jeffreyi). There are currently studies underway to test the minor species (western hemlock (Tsuga heterophylla), Sitka spruce (Picea sitchensis), and Western red cedar (Thuja plicata)) grown at Humboldt. These tree species will also be tested on sites within the natural seed zone of the seedlings.

One of the advantages of using the RGC tests is that it can give an evaluation of the condition of the seedling before planting, rather than after the seed-lot has been planted. The results of the tests can help detect errors in tree handling or in tree culture in the nursery. Trees stored for long periods of time can be tested before planting and an evaluation made of the results of the tests before the trees are actually outplanted. Other tests do not have that advantage. Management implications are that the manager can then use the test results to determine which seed source to use for a particular unit; how many trees of the seed lot to plant; and obtain the desired stocking levels, based on the percent of growth in the test facility of the seed lot. Condition of the trees (the potential for survival and growth) can be considered. Vigorous trees can be planted in difficult planting spots while trees that are not so vigorous can be planted in places that are not as critical.

The potential savings from using tested trees that can be realized are many. First a seed lot that is doing poorly in the tests should be destroyed or be planted on a non-difficult area. Second, the savings for replanting can be significant. Third, the numbers of trees that need to be planted can be determined based on the test results. More or fewer trees than the standard can be planted to obtain the desired level of stocking, other factors being equal. The amount of post planting damage or losses from animals, brush competition or other factors also needs to be considered in assessing potential losses.

CONCLUSIONS

One of the major advantages of using RGC is the simplicity of reading the overall results. Survival percentages can be calculated as soon as the final results of the tests are read and recorded. An early indication of poor performance is given by the amount of water being used by the seedling test lot. Results of the tests are available within 30 days of the beginning of the tests. Testing can begin as soon as the trees are lifted from the nursery beds and shipped to the test facility. As an alternative, trees can be stored in the cold storage facility and tested upon removal to give an overall indication of the quality of the seedlings after the nursery treatments and storage facility have been allowed to accumulate. The overall costs of the tests are very low for each seed source tested. The $86 cost is minimal compared to what could be lost by planting poor quality seedlings and having to replant the area. The overall time required and the manpower needed to do the tests is relatively small once the facility has been constructed.

REFERENCES

(1). Wood, M., "Growing successful seedlings", Forestry Research West. USDA Forest Service, January, 1983.

(2). Brissette, J. C. And Roberts, T. C. "Seedling size and lifting date effects on Root Growth Potential of Loblolly pine from two Arkansas nurseries". Tree Planters Notes. Vol. 35, No. 1., Winter, 1984.

(3). ibid.

(4). ibid.

(5). Jenkinson, J. L., Personal Communication. Feb. 1984.

(6). Jenkinson, J. L., "Seed Source Lifting Windows Improve Plantation Establishment of Pacific Slope Douglas-fir." Research Paper. 1984

(7). Jenkinson, J. L., Personal Communication. Feb. 1984.

(8). Jenkinson, J. L., and James A. Nelson, "1-0 Douglas fir: A Bare Root Planting Option." Western Forestry Nursery Council. 1982.

(9). Jenkinson, J. L., Personal Communication. Mar. 1985.

APPENDIX A

R G C

SEED CODE 205-121-061-05000-2.0

DISTRICT WALDPORT DATE IN 02-02-84

NURSERY HUMBOLDT DATE OUT 03-01-84

NURSERY LOT NO. 125-18

TRAY	BATH	TREE	COUNT	<10	10	20	30	40	50
1	2	1	99						X
		2	71						X
		3	25			X			
		4	67						X
		5	3	X					
		6	78						X
		7	90						X
		8	44					X	
		9	99						X
		10	63						X
2	6	11	79						X
		12	57						X
		13	72						X
		14	51						X
		15	47					X	
		16	56						X
		17	23			X			
		18	76						X
		19	69						X
		20	67						X
3	10	21	59						X
		22	35				X		
		23	39				X		
		24	22			X			
		25	50						X
		26	26			X			
		27	32				X		
		28	29			X			
		29	22			X			
		30	20			X			
TOTALS				1	0	7	3	2	17

RGC FORM 4-84

COMMENT: This lot should do very well in the field with over 95% expected to do well.

R G C

SEED CODE 205 12021 203 2-0

DISTRICT WALDPORT DATE IN 02-07-84

NURSERY HUMBOLDT DATE OUT 03-05-84

NURSERY LOT NO. 125-09

TRAY	BATH	TREE	COUNT	<10	10	20	30	40	50	
1	4	1	75						X	
		2	75						X	
		3	0	X						
		4	0	X						
		5	61						X	
		6	68						X	
		7	17		X				X	
		8	62						X	
		9	0	X						
		10	28			X				
2	8	11	35				X			
		12	23			X				
		13	47					X		
		14	30				X			
		15	62						X	
		16	58						X	
		17	28			X				
		18	4	X						
		19	20			X				
		20	57						X	
3	12	21	10		X					
		22	25			X				
		23	42					X		
		24	5	X						
		25	63						X	
		26	11		X					
		27	39				X			
		28	50						X	
		29	37				X			
		30	23			X				
TOTALS				5	3	6	4	4	8	

RGC FORM 4-84 COMMENT: Seed lot should survive at 80% under field conditions.

APPENDIX B

RGC TEST INSTRUCTIONS

INTRODUCTION

There is a strong relationship between a seedling's capacity to grow roots and its ability to survive and grow on a field planting site. The RGC test, if done within 6 weeks of spring planting, will give a reliable estimate of field performance.

1. TREE SELECTION

Obtain a random sample of 75 to 100 trees from each of the lots to be tested. Randomly select 30 average trees from each sample. Do not select exceptionally large or exceptionally small trees. Protect the trees until they can be planted in the test trays. Keep the tops and roots moist and covered at all times. Do not jeopardize the test by being careless with the sample trees.

2. PLANTING THE TREES

Fill the bottom 2 to 3 inches of each test tray with moist potting soil (use equal volumes of river sand, perlite, shredded redwood soil conditioner, and a sandy loam forest soil). Leave enough space for trees with 9-inch roots. Set the tray at an angle so that you can place potting soil on the lower side of the tray and firm it in place. Place the trees to be planted in the tub of soil and thoroughly cover the roots. Then take the largest tree in the group and place it in one end of the prepared tray, making sure the roots are suspended properly. The largest tree is selected because it is the easiest to plant when there are no others in the tray. It is the hardest to plant when the tray has other trees. Select the next tree at random, and place it beside the first tree in the tray. Continue to place trees in

the tray until you have 5 or 10 equally spaced trees. Once the trees are in, fill the upper side of the tray with soil mixture. When the tray is full, stand it up and rap it gently on the counter to settle the soil. Add soil until the tray is again full. Set the tray aside and continue to plant the other 2 or 5 trays with the balance of the test lot.

3. WATERING THE TREES

After all of the trees have been planted, move the trays into the greenhouse. Irrigate the trees until water flows from the drain holes. Do this with several small waterings to avoid washing the soil from the tray. Let the trays drain for at least 12 hours. Weigh each tray to obtain its initial gross weight, and insert a plug in the drain hole. Be sure each tray is marked with a tag showing the lot number, tray number, and date of planting.

After all of the trays have been weighed and plugged, immerse them to the rim in the water baths. Ballast weights may be needed to hold the trays in place. Be very careful that the motion of placing each tray does not upset or flood trays in the bath. Do not place all trays from the same lot in the same bath. If something should happen to one bath, then only 1 tray per lot will be lost, not all 3 or 6.

4. THE TEST ENVIRONMENT

Maintain the trees in the greenhouse for 4 weeks. Hold the water bath temperature at 68 degrees F. Air temperature in the greenhouse should be kept near 62 degrees at night and 75 degrees

during the day. Set the daylight period at 16 hours, using an appropriate bank of lights to extend the natural photoperiod.

5. WEEKLY WEIGHING

Weigh all trays weekly, for example, on each Tuesday. Remove the trays from the water baths and remove plugs from the trays. Place each tray on the scale, record its current weight, and add enough water to restore the tray to its initial weight. Wait 20 minutes for the water to percolate into the soil. Replug the drain hole, and transfer the tray back to the appropriate bench and water bath.

6. TERMINATING THE TEST

After 4 weeks, remove the trays from the baths. Weigh the trays one final time. Remove the trees from the trays, watering them thoroughly first to prevent root breakage. After all of the trees are washed free and clean, place them in wet paper towels to keep the new roots covered and moist. Store the wrapped trees in polyethylene bags at 35 degrees F. Determine all new root growth within 3 days, before the new growth turns brown.

7. COUNTING THE NEW ROOTS

For each tree, count and record the number of new roots that grew **more than 1.5 centimeters.** You may sometimes have to use the magnifying light to determine which roots exceed 1.5 cm. If most trees do not have at least 10 new roots longer than 1.5 cm, then count the number shorter than 1.5 cm, to assess marginal lots.

8. SUMMARIZING THE RESULTS

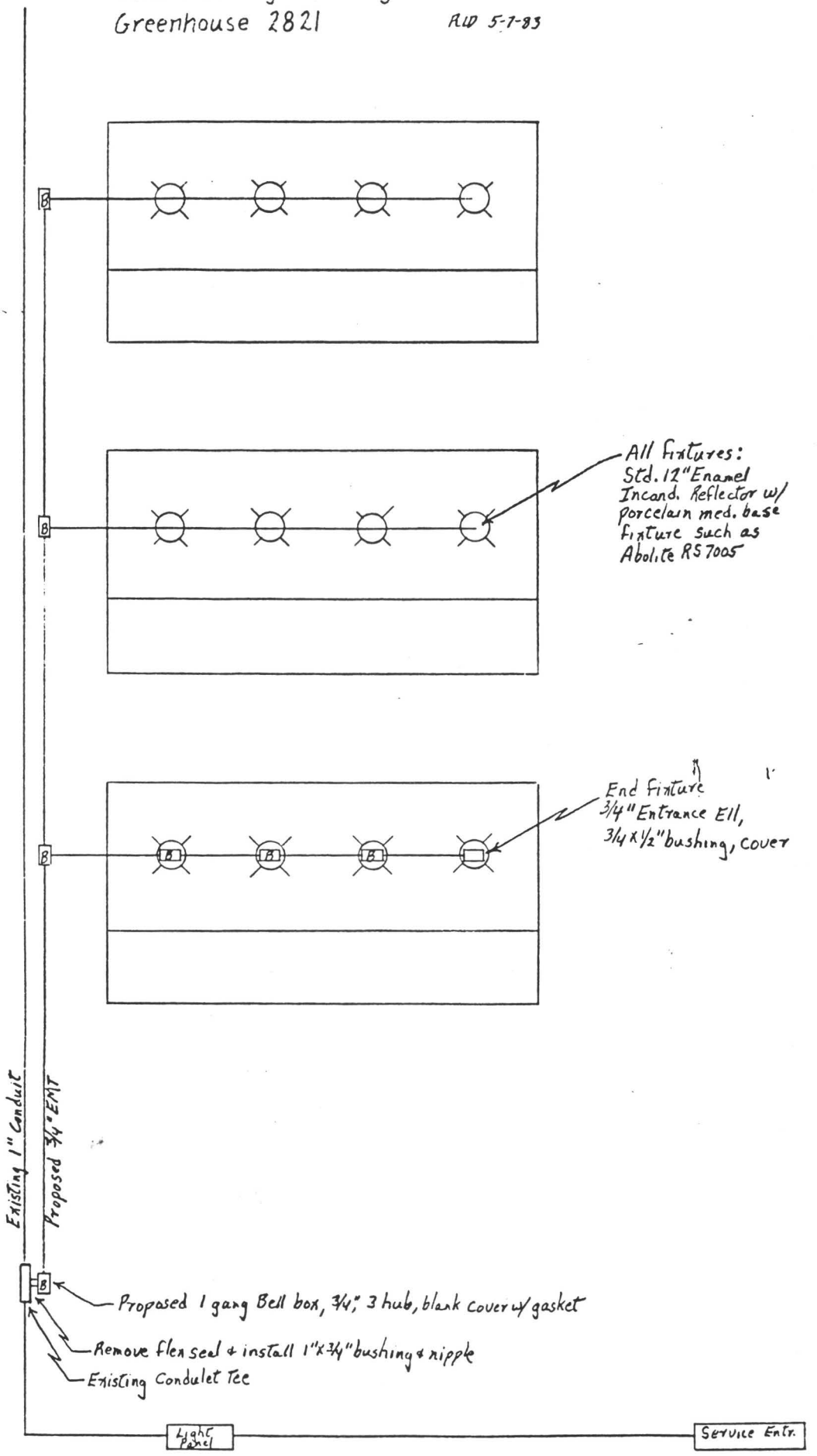
For each sample, determine the percentage of trees having 10 or more roots that grew at least 1.5 cm during the test.

Determine the percentage having 20 or more; 30 or more; 40 or more; and 50 or more.

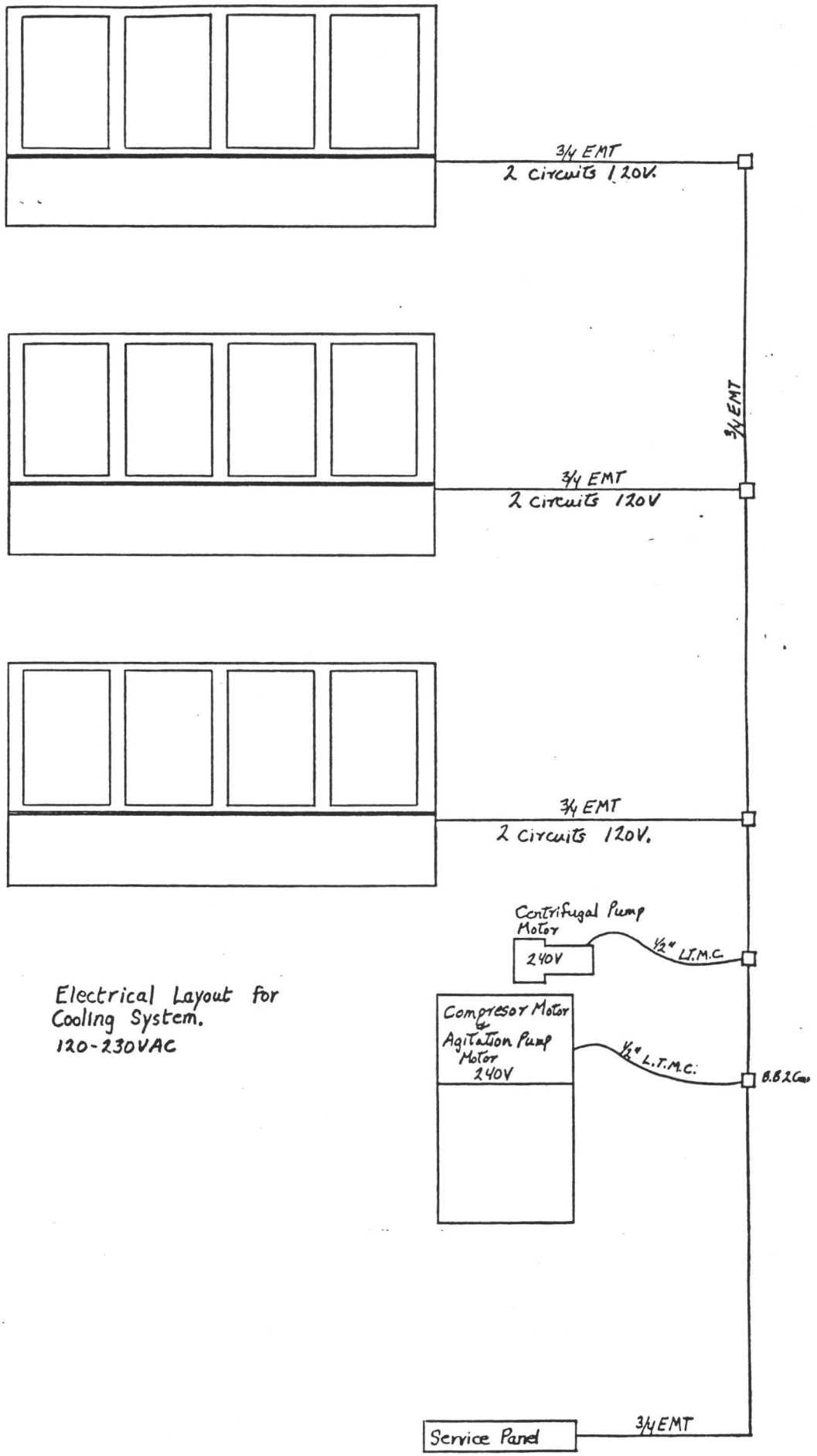
For each lot of Douglas-fir planting stock destined for the Siuslaw NF, at least 90% of the tested seedlings should have an RGC greater than 10 (number of roots elongated 1.5 cm or more in the test environment for each tree). On all districts on the Siuslaw, first year field survivals were 90 to 99% when 90% of the planted trees had an RGC of 10 or higher (Humboldt Nursery Administrative Studies, 1977-1981). The various test planting sites included south and west slopes, and no site ever resulted in a critical RGC higher than 10. Thus, field survival is expected to be 90% or higher for lots in which 90% of the sampled seedlings have an RGC of 10 or higher.

APPENDIX C

PROPOSED Light Wireing Plan
Greenhouse 2821 RLD 5-7-83

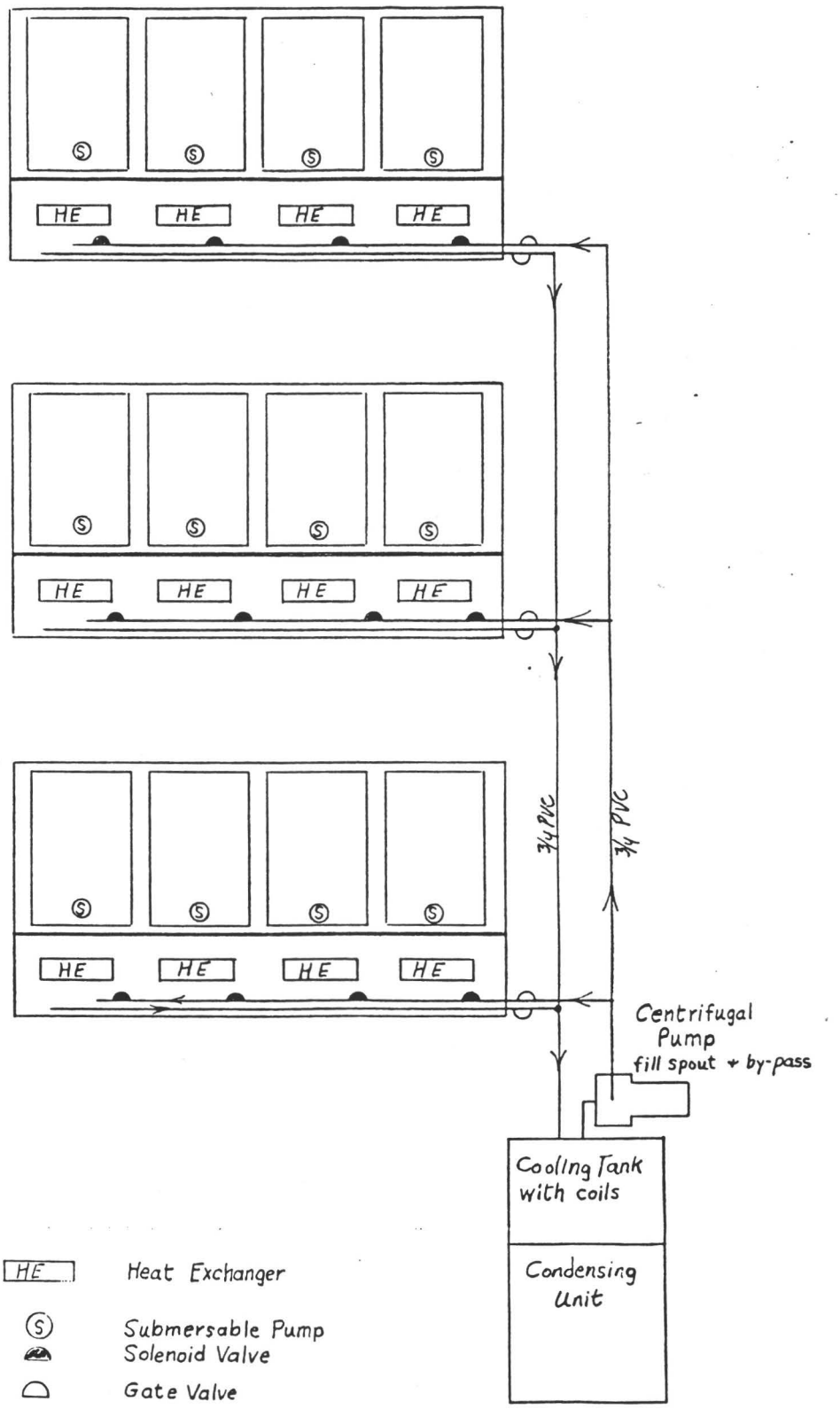


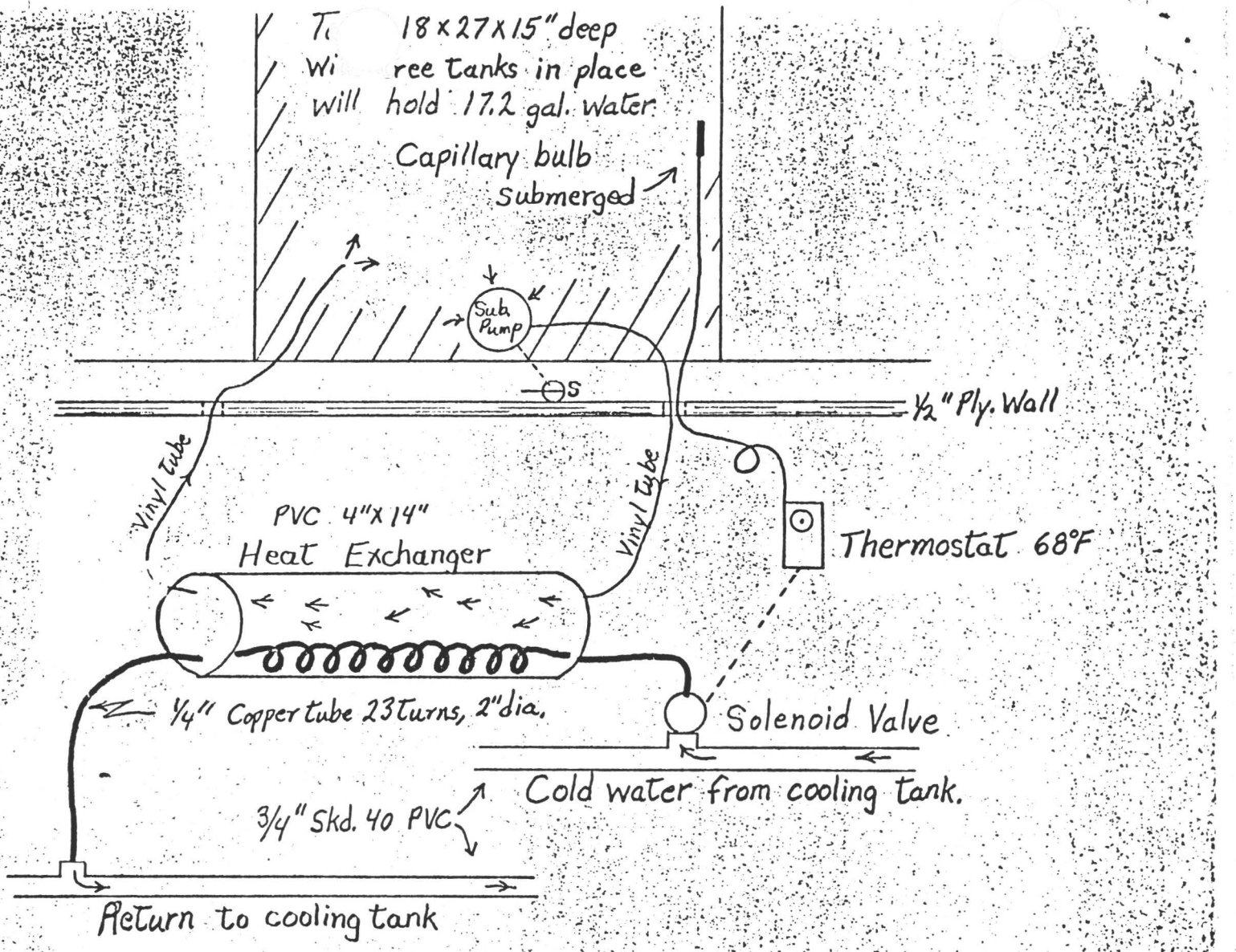
12 self ballested mercury vapor lights
12 x 250 watts = 3000 wt. ; 26 Amps
Proposed one time clock & one 2 pole relay, both existing
Split lighting on two 120 V. 20 Amp. circuits useing #12 THWN
Disconnect all other photo lighting from breakers



Electrical Layout for Cooling System.
120-230VAC

Water Cooling Layout





Single Heat Exchanger

APPENDIX D

1985 RGC SUMMARY

SUMMARY OF ALL LOTS, ALL NURSERIES

TOTAL TREES SAMPLED = 1465

	NUMBER	PERCENT
NO. WITH LESS THAN 10 ROOTS WITH 1.5 CM	22	1.5
NO. WITH AT LEAST 10 ROOTS WITH 1.5 CM	71	4.8
NO. WITH AT LEAST 20 ROOTS WITH 1.5 CM	163	11.1
NO. WITH AT LEAST 30 ROOTS WITH 1.5 CM	218	14.8
NO. WITH AT LEAST 40 ROOTS WITH 1.5 CM	184	12.5
NO. WITH 50 OR MORE ROOTS WITH 1.5 CM	805	54.9
TOTAL	1465	

BY NURSERY

	J.H.STONE (25 LOTS)		HUMBOLDT (17 LOTS)		D.L.PHIPPS (15 LOTS)	
<10 ROOTS	4	0.5%	11	3.0%	7	1.7%
10 ROOTS	21	2.9%	22	6.0%	28	7.1%
20 ROOTS	62	8.7%	57	15.6%	44	11.2%
30 ROOTS	106	14.9%	59	16.1%	53	13.5%
40 ROOTS	90	12.6%	45	12.3%	49	12.5%
50+	424	59.7%	171	46.8%	210	53.8%
TOTALS	710		365		390	